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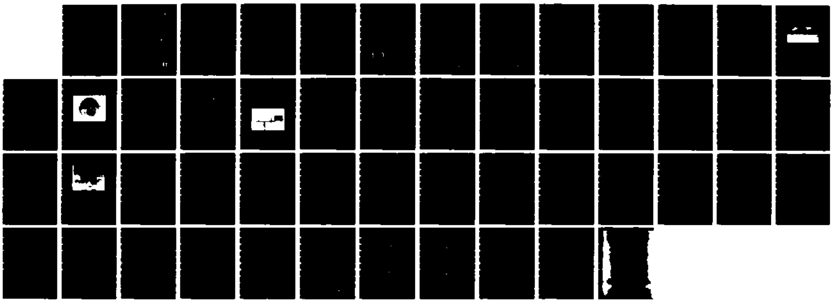

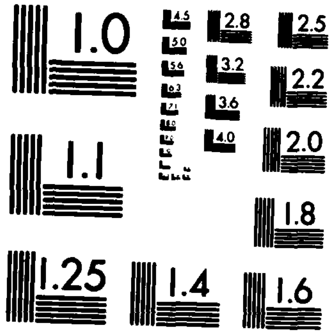

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Tactical Visibility Meter

EUGENE Y. MOROZ
LEO P. JACOBS

24 October 1983

METEOROLOGY DIVISION PROJECT 6670
AIR FORCE GEOPHYSICS LABORATORY
HANSCOM AFB, MASSACHUSETTS 01731

AIR FORCE SYSTEMS COMMAND, USAF

This report has been reviewed by the ESD Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS).

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FOR THE COMMANDER

for KENNETH M. GLOVER
Chief, Ground Based Remote Sensing Branch
Meteorology Division

ROBERT A. MCCLATCHEY
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Accurate and timely visibility information is required by the Air Weather Service in support of Air Force tactical bare-base operations. The Air Force Geophysics Laboratory (AFGL) undertook a program to develop a tactical visibility meter (TVM) to satisfy this requirement. A prototype meter was designed and fabricated by Wright & Wright, Inc., Oak Bluffs, Mass. The meter measures the atmospheric scattering coefficient in the forward direction. Visibility is inferred from the measurement. The operation of the prototype meter was successfully demonstrated by AFGL in tests conducted

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at its Weather Test Facility, Otis AFB, Mass. In the next phase of the development, Wright & Wright, Inc., was tasked to design and fabricate a cost-effective preproduction version of the TVM. This report describes the current development, test, and evaluation of the TVM.

Summary

A program has been initiated at AFGL to develop a visibility meter in support of Air Force tactical bare-base airfield operations. A prototype tactical visibility meter (TVM) has been successfully demonstrated. The development has continued with the design and fabrication of a cost-effective preproduction version of the TVM. The new meter has undergone testing in test chambers and in the field. The results are presented.

Preface

The authors wish to express their appreciation to various individuals for their support, which resulted in the successful development, test, and evaluation of the preproduction Tactical Visibility Meter (TVM). First, we wish to acknowledge the individual who was responsible for the design and fabrication of the TVM, Mr. David Wright. Also, the generosity of Mr. Frederick Brousaides and Dr. David Burnham that allowed us to participate in the Calspan and Elgin Tests is gratefully appreciated. The technician assistance provided by Messrs. Clyde Lawrance and Ralph Hoar at AFGL's Weather Test Facility deserves special recognition. We are grateful to Mrs. Joan Ward for her conscientious effort in providing programming assistance. Lastly, a special thanks to Mrs. Donna Velardi for typing the manuscript.

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1. INTRODUCTION

The Air Force Geophysics Laboratory (AFGL) has undertaken a program to provide Air Weather Service (AWS) with the capability of obtaining accurate and timely visibility information in tactical bare-base airfield environments. This was part of a larger AFGL effort whose objective was to develop an Automated Tactical Meteorological Observing System (ATMOS).[1] The ATMOS effort was curtailed because of manpower changes within the Meteorological Division of AFGL.

During the first phase of the development, a prototype tactical visibility meter (TVM) was designed and fabricated by Wright and Wright, Inc., Oak Bluffs, Mass.[2] Testing of the prototype TVM by the contractor and by AFGL at its Weather Test Facility (WTF), Otis AFB, Mass., demonstrated that the meter was capable of meeting its design goals. The successful demonstration resulted in Wright and Wright being tasked to design and fabricate a cost-effective preproduction version of the prototype meter under Air Force Contract F1962-81-C-0012.

(Received for publication 13 October 1983)

1. Moroz, E.Y., and Brousaides, F.J. (1980) Survey of Sensors for Automated Tactical Weather Observations, AFGL-TR-80-0195, AD A094121.
2. Moroz, E.Y., Sheets, S.J., and Morrissey, J.F. (1982) Evaluation of Selected Sensors for Automated Tactical Weather Observations, AFGL-TR-82-0191, AD A122172.

In the period between prototype demonstration and the present contract, Wright and Wright began an in-house effort to develop a commercial forward-scatter measuring visibility meter. At the time of preproduction TVM contract award, Wright and Wright had completed the fabrication of the commercial version, the FOG-15 Visual Range Meter. The FOG-15 had the design features required by the TVM except for minor differences in calibration and an option to operate covertly. To facilitate the development of the TVM, it was mutually agreed that the FOG-15 would be tested to evaluate the contractor's TVM design.

The evaluation model was tested extensively. Tests were conducted at both the Calspan and Eglin AFB environmental chambers, and at the contractor's plant and the AFGL/WTF. During the evaluation test phase, the meter was modified a number of times. A preproduction TVM was ultimately fabricated based on the final version of the FOG-15. Testing of the TVM was conducted at WTF. This report describes the development and testing of the TVM and presents test results.

2. PREPRODUCTION TACTICAL VISIBILITY METER

Wright and Wright was awarded Air Force Contract No. F19628-81-C-0018 for the design and fabrication of a preproduction tactical visibility meter. The major design requirements of the new meter were:

(1) It should determine the atmospheric extinction coefficient in all types of obscuring media throughout a range of 0.15 km^{-1} to 65 km^{-1}. For a contrast threshold of 0.05, these extinctions equate to a 45 m (150 ft) to 20 km (12 miles) visual range, respectively.

(2) The instrument should be configured so that it can be readily transported and installed. One person should be capable of installing the instrument; the instrument should require no realignment.

(3) Means should be provided to calibrate the instrument to within ±1 percent of equivalent extinction coefficient under field conditions. The instrument should be designed to maintain its calibration to within ±5 percent of equivalent extinction coefficient for a period of 6 months under normal operating conditions. The detailed specification is presented in Appendix A.

The new meter is physically quite different from the prototype TVM. It consists of a transmitter and receiver which are mounted on a crossarm. The meter is shown in Figure 1. The contractor kept the new design simple and inexpensive, using stock materials where possible. The transmitter and receiver housings are industrial stainless steel containers. The front faces of the housings are made from Lexan, a strong, durable, plastic material. Each Lexan face is optically

masked except for the portion used as the front optical element in both the receiver and transmitter.

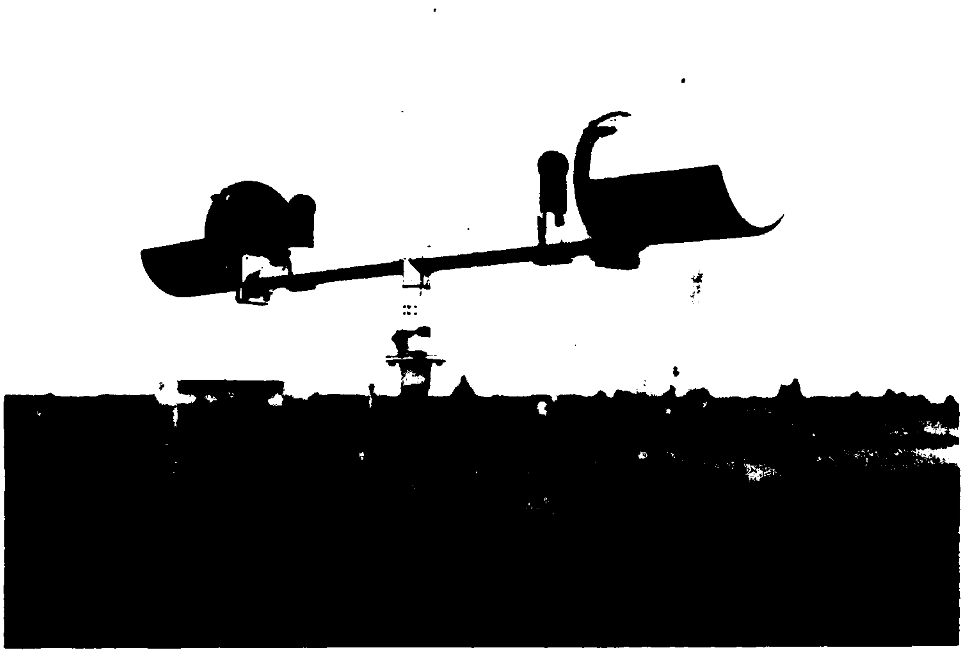

Figure 1. Evaluation Model TVM (FOG-15) at AFGL/WTF, Otis AFB, Mass.

The electronics are located within the housings except for the RFI filter and the control for the optical block heaters located in the crossarm conduit junction box. Two sun shields can be mounted on the housings to reduce the effect of solar heating on the system (not shown in Figure 1).

Two calibration points can be obtained with the TVM calibration system. The system consists of a pair of optical attenuators and a translucent plastic light-scatterer. The attenuators are located on a four-position filter wheel with two attenuated positions, one normal unattenuated operation position, and one containing the filter for covert operations. During calibration, the plastic light-scatterer is mounted in a fixed position at the center of the crossarm, and the filter wheel is rotated in turn to the two attenuator positions.

The transmitter source is a quartz halogen light mechanically modulated at a nominal 550 Hz. To eliminate any direct transmitted light, the transmitter light

beam is shaped to have no center portion. The beam has an outer cone limit of 40 degrees and an inner limit of 16 degrees. The receiver is positioned 4 ft from the transmitter. Its field of view (fov) matches the shape of the transmitted beam. The light beam and the fov of the receiver are shaped by optically masking the Lexan faces as well as by mounting optical blocks on the crossarm. The faces have additional masking to avoid any optical interference with the crossarm. The transmitter/receiver intersection is a partial toroid with a volume of 25,500 cc (0.9 ft^3). The volume scattering coefficient is measured in the forward direction over a range of 16-40 degrees.

The instrument was designed assuming its output voltage (V) was linearly related to atmospheric extinction (σ). The following relation was used throughout the testing: $\sigma = 10V$ (km^{-1}).

3. TESTING

The demonstration FOG-15 was extensively tested during the design evaluation phase. Evaluation tests were conducted at the contractor's plant and at AFGL as well as in test chambers. The chamber tests were performed at the Calspan Environmental Test Chamber, Ashford, N.Y., and at the McKinley Climatic Laboratory, Eglin AFB, Fla. Acceptance testing of the preproduction TVM was performed by the contractor at his plant. Field tests of the preproduction model were conducted by AFGL at the Weather Test Facility, Otis, AFB, Mass. These tests are continuing.

The demonstration meter was included in a series of fog/haze chamber tests that were conducted to aid in the evaluation of several extinction meters being developed for AFGL by HSS Incorporated, Bedford, Mass. The tests were performed in the Calspan 600 m^3 cylindrical environmental test chamber[3] as shown in Figure 2.

Calspan used three reference meters to measure the visible extinction in the chamber over its operating range of 0.01 km^{-1} to 1110 km^{-1}. These meters were a 2.7 m and an 18.3 m baseline transmissometer, and an MRI Model 1550B Integrating Nephelometer. Also, an AFGL-owned EG&G Model 207 Forward Scatter Meter (FSM) was installed for use as a reference meter. The results of the FSM were not used in the evaluation because the meter, unfortunately, performed er-

3. Hanley, J.T. (1982) Final Report, Documentation of Extinction and Particle Size Measurements for Chamber Tests of May 1982, Arvin Claspan, Advanced Technology Center, Buffalo, N.Y.

ratically. It was learned later that its photocell had developed an intermittent internal connection.

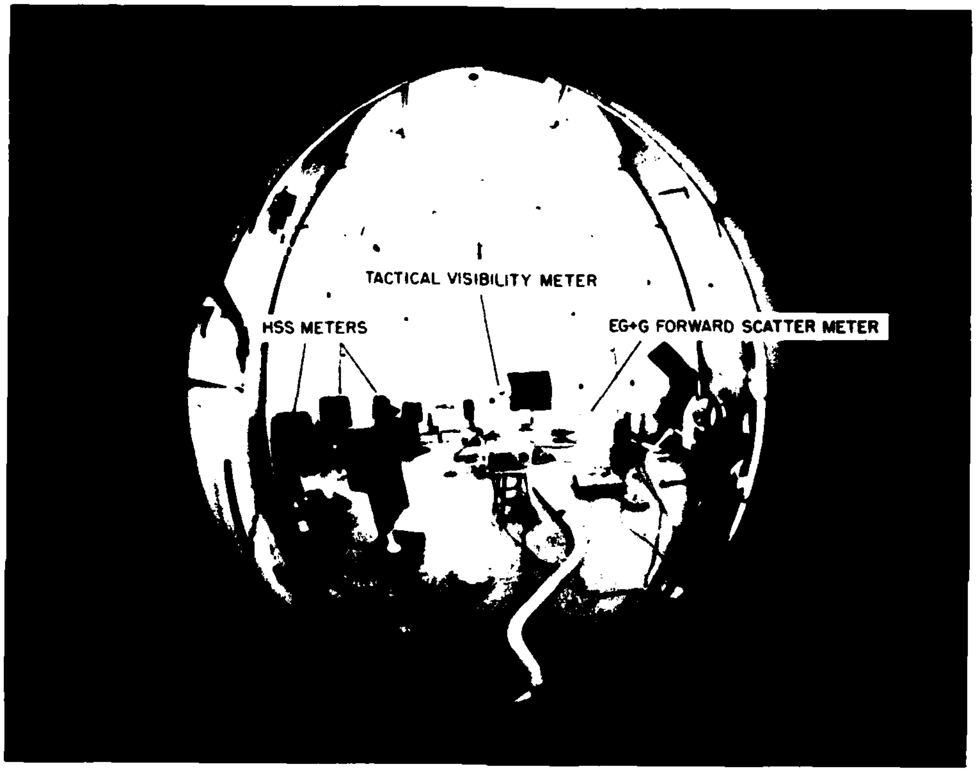

Figure 2. Extinction Meters Being Tested in Calspan Environmental Chamber, Ashford, N.Y.

Test conditions were created in the Calspan chamber by expansion of near-saturated air to form fog, or by burning either a salt pyrotechnic or phosphorus to generate a hygroscopic haze. A listing of the 14 tests is shown in Table 1. The TVM was operated in 10 of the tests, 6 fog tests and 4 haze tests. No fog formed during Test No. 2, and the results of Test No. 5 are suspect.

It was anticipated that stray light reflecting off the chamber wall would produce a large background signal. Therefore, light baffles for the meters were made for use during the tests. The baffles were large, so it was not practical to use more than one baffle with each meter. The background signal was minimum when

Table 1. Fog and Haze Tests Conducted at the Calspan Environmental Test Chamber, Ashford, N.Y.

TEST NO.	1982 DATE	
1	3 May	Haze; mixed salt aerosol @ low RH
2	4 May	Fog; ambient nuclei, fog did not develop
3*	4 May	Fog; ambient nuclei
4*	4 May	Fog; ambient nuclei
5*	4 May	Fog; cigar smoke nuclei, questionable data
6*	4 May	Haze; mixed salt aerosol @ high RH
7*	5 May	Fog; ambient nuclei
8*	5 May	Fog; ambient nuclei
9*	5 May	Fog; cigar smoke nuclei
10*	5 May	Haze; mixed salt aerosol @ high RH
11	6 May	Fog; ambient nuclei
12	6 May	Fog; cigar smoke nuclei
13*	6 May	Haze; mixed salt aerosol @ high RH
14*	7 May	Haze; white phosphorus @ low RH

*The TVM was operated during these tests.

the projector faced the baffle. An evaluation of the background on 6 May showed that the TVM produced an output of 200 MV when it looked at the wall (no baffle). The output lowered to 26 MV when its receiver looked into the baffle and was only 10 MV when the projector faced the baffle. During the tests, the TVM background signal varied from 9 to 30 MV in "clear" conditions. An arbitrary 20 MV background signal was subtracted from the TVM test data.

The TVM "zero" signal changed from a value of 0.0 MV on 4 and 5 May to 1.9 MV on 7 May. The "zero" shift may account for some of the change in the 2 calibrate signals that decreased slightly during the test, approximately 0.5 percent.

A comparison plot of the TVM vs a "combined" Calspan output for the 10 TVM runs is shown in Figure 3. The overall agreement between the TVM and the Calspan data is good, considering the inhomogeneities that were observed in the chamber during transient conditions. After the data were plotted, it was learned that

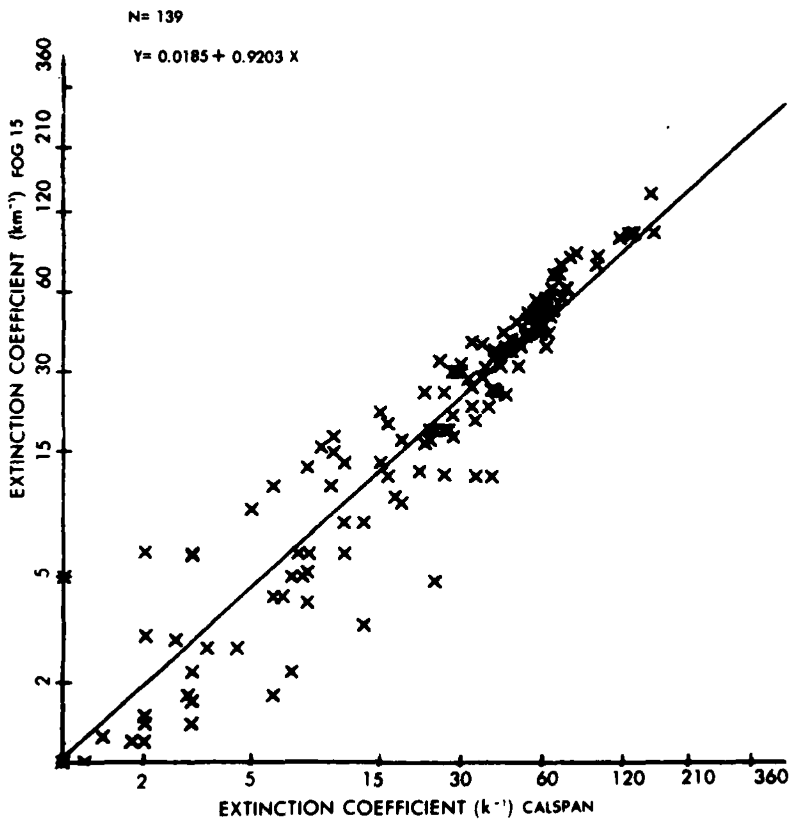

Figure 3. Comparison of Measurements Obtained by TVM and Calspan Extinction Meters in Fog and Haze

the MRI nephelometer's calibration was off by a factor of 0.6. Correcting the MRI data would reduce the scatter in the plot for extinctions below 7 km^{-1}. This correction was not done because additional modifications were made to the TVM after this series of tests. Time plots of the individual test runs are given in Appendix B.

The Transportation Systems Center (TSC) of the Department of Transportation (DOT) conducted a visibility sensor experiment at the Eglin AFB Climatic Laboratory's large test chamber in June 1982.[4] The primary goal of the experiment was to examine visibility sensors that had potential to measure Runway Visual Range (RVR) for Category IIIb operations. Another goal of the experiment was to evaluate sensors that had potential to determine Runway Visibility (RVV) for FAA's

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4. Burnham, D.C. (1983) Evaluation of Visibility Sensors at the Eglin Air Force Base Climatic Chamber, DOT/FAA/PM-83/29.

Automatic Weather Observing System (AWOS). Various obscurations were created in the chamber for the tests, including fog, rain, freezing rain, and snow. The visibilities created ranged from an RVR of 100 ft to an RVV of 5 miles.

AFGL volunteered to provide and operate its TVM as well as 2 EG&G FSM 207s for the experiment. Nine other visibility meters were operated during the test, including a commercial FOG-15. Some of the meters, including the TVM, were affected by the chamber lights. As a result, the tests were run with the lights off. The TVM was sufficiently distant from the chamber walls so that it was not necessary to use a baffle to suppress the modulated projector light reflected off the wall, as in the Calspan tests.

During the experiment, the fog density increased to the point where the TVM's signal was clipped. The TVM was modified with a gain switch to lower its gain. The TVM showed significant window contamination during the precipitation tests (Figure 4). The TVM housings were covered with thermal blanket material to in-

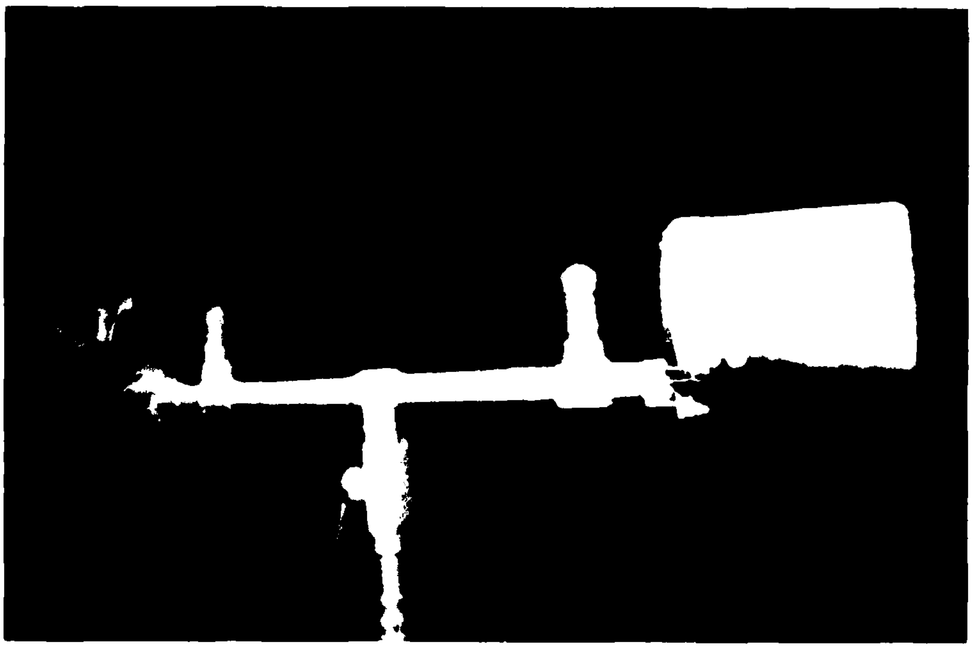

Figure 4. Effect of Freezing Precipitation on TVM During Testing at Elgin AFB, Fla.

crease the internal heat flow out through the windows instead of out through the metal housings. This action corrected the deficiency. Only qualitative results

were obtained from the precipitation tests because chamber conditions were not homogeneous. In the stable fog case that was analyzed by TSC, the TVM compared favorably with the HeNe laser calibrator. It correlated well with the calibrator, and its response showed a slope of approximately 0.9. The conclusion from the experiment was that all the sensors tested showed reasonable promise of measuring Category IIIb visibility conditions.

The contractor conducted a number of performance tests to determine the stability of the meter's output: (1) with time; (2) with variations of electrical input power; and (3) with the TVM's receiver exposed to a flashing emergency beacon. With the calibrator in place, the test criterion was that the output voltage would remain constant to ±1 percent. The meter's output stabilized within 1 hour after turn-on; the output changed slightly more than ±1 percent when the input voltage was varied over a range of 105 to 125 V; and its output changed less than 1 percent during the flashing-light test. The plotted data are given in Appendix C. The preproduction TVM had the following characteristics as determined by the contractor:

(1) Capability of measuring extinction from 100 km^{-1} to 0.2 km^{-1} with an accuracy of ±0.1 km^{-1}. Using a contrast threshold of 5 percent, this is equivalent to a Visual Range of 30 m (100 ft) to 14.5 m (9 miles) respectively.

(2) An integration time constant of 27 sec. For test purposes, the integration time is 2.7 sec.

(3) An operating temperature range from -20°C to +50°C

(4) A maximum power requirement of 300 watts, 105-125 VAC, 60 Hz single phase

(5) A total weight of 19 kg (42 lb) and overall size of 163 cm L x 46 cm H x 25 cm W (64" x 18" x 10")

The final version of the preproduction model TVM was installed at the AFGL/WTF, Otis AFB, Mass., in August 1982. However, the test program did not start until late fall. The delay was caused mainly by problems associated with processing the pulse output of the transmissometers at the site. The transmissometer system was made operational by the middle of November, when the test program started. The sensors used in the Otis evaluation were located so that the centers of their measurement volumes were located within a 10-m circle. The comparison sensors included in the evaluation were:

(1) a 152.4 m (500 ft) baseline transmissometer, AN/GMQ 32 [500], *

(2) a 91.4 m (300 ft) baseline transmissometer, AN/GMQ 32 [300], *

(3) an EG&G Model 207, Forward Scatter Meter [X], * and

(4) a Wright and Wright Model FOG-15, scatter meter [F15]. *

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*In processing the data, the sensors were referred to by the designation in brackets; the preproduction model TVM's designation was "FOG."

At the Otis site, data were processed and collected by the Modular Automated Weather System (MAWS). Its configuration was similar to the MAWS configuration used in the Scott AFB Air Weather Service automation experiment.[5] A set of data at Otis was designated by its MAWS number; each set contained approximately 2 weeks of data. MAWS recorded the average of 5 outputs from the sensors each minute. Therefore, a data set contained approximately 19K measurements from each scatter meter and 17K measurements from the transmissometers. (No comparison measurements were taken while the transmissometers were in their background mode.) The data sets evaluated were MAWS 86 through MAWS 93, 19 November 1982 through 11 March 1983. (MAWS was down 11-15 February.)

A summary of the comparison data is given in Table 2. Presented in the summary are:

Table 2. Summary of Comparisons of Preproduction TVM to Various Visibility Sensors at AFGL/WTF, 19 Nov 1982-11 Mar 1983. The summary shows the equations representing the linear least-squares fit to the extinction coefficient (km^{-1}) data and the correlation coefficient (r) between sensors

MAWS NO./DATE	x: 300 y: FOG	x: 500 y: FOG	x: X y: FOG	x: FOG y: F15	x: 300 y: 500
86 19 NOV - 03 DEC 82	y = -0.05 + 1.11x r = 0.99	y = -0.16 + [illegible] r = 1.00	y = [illegible] r = 1.00	y = -0.01 + 1.10x r = 1.00	y = 0.08 + 0.80x r = 1.00
87 03 - 17 DEC 82	y = 0.01 + 0.57x r = 0.90	y = 0.01 + 0.53x r = 0.88	y = [illegible] + 0.93x r = [illegible]	y = -0.02 + [illegible] r = 1.00	y = 0.04 + 0.60x r = 0.89
88 17 - 30 DEC 82	y = -0.06 + 1.05x r = [illegible]	y = 0.00 + [illegible] r = [illegible]	y = [illegible] r = [illegible]	y = -0.01 + 1.16x r = 1.00	y = -0.06 + [illegible] r = 1.00
89 30 DEC 82 - 14 JAN 83	y = [illegible] r = [illegible]	[illegible] r = [illegible]	[illegible] r = [illegible]	y = [illegible] + 1.20x r = 0.99	y = [illegible] + 0.98x r = 1.00
90 14 - 28 JAN 83	y = [illegible] r = 0.98	[illegible] r = [illegible]	y = [illegible] r = [illegible]	y = -0.03 + [illegible] r = 1.00	y = -0.02 + 0.95x r = 0.99
91 28 JAN - 11 FEB 83	y = -0.03 + [illegible] r = 0.99	y = [illegible] r = [illegible]	y = [illegible] r = [illegible]	y = -0.02 + 1.21 r = 1.00	y = [illegible] + 1.11x r = 0.99
92 15 - 25 FEB 83	y = [illegible] r = [illegible]	y = [illegible] r = [illegible]	y = [illegible] r = [illegible]	y = [illegible] r = [illegible]	y = [illegible] r = [illegible]
93 25 FEB - 11 MAR 83	y = [illegible] r = [illegible]	y = [illegible] r = [illegible]	y = [illegible] r = [illegible]	y = -0.01 + 1.21 r = [illegible]	y = [illegible] r = 0.85

(1) the equations representing the linear least-squares fit to the extinction coefficient data, and

(2) the correlation coefficient (r) of the extinction values.

The data reflect the problems encountered in keeping the transmissometers oper-

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5. Tahnk, W.R., and Lynch, R.H. (1978) The Development of a Fixed Base Automated Weather Sensing and Display System, AFGL-TR-78-0009, AD A054805, Instrumentation Papers No. 260.

ating properly. During MAWS 87, MAWS 90, and MAWS 92, there were problems with transmissometer alignment, coverters, and pulse amplifiers that resulted in poor calibration and correlation data. The three forward-scatter meters maintained stable calibrations throughout the test period. The correlation coefficients between the various sensors are extremely high except for those data when the transmissometers were not operating properly. During the test, the transmissometers were routinely recalibrated and their windows cleaned. No routine maintenance was performed on the scatter meters. The TVM was calibrated before and after the test.

One of the data sets, MAWS 88, was examined more closely by separating the extinctions coefficients into range bins of < 0.4, ≥ 0.4, < 4.0, and ≥ 4.0. These data are presented in Table 3, where the number of data points in each range are

Table 3. Comparison of Preproduction TVM to Various Visibility Sensors at AFGL/WTF for MAWS 88, 17-30 Dec 1982. The comparison shows (1) the number of measurements in the data set; (2) the equation representing the linear least-squares fit to the data over the different ranges of extinction coefficients being considered; and (3) the correlation coefficient (r)

Extinction Coefficient (σ) Range	x: 300 y: FOG	x: 500 y: FOG	x: [illegible] y: FOG	x: FOG y: [illegible]	x: 300 y: 500
All σ's	16,980 y = -0.06 + 1.05x r = 1.00	16,980 y = 0.00 + 0.99x r = 1.00	18,861 y = 0.02 + 0.93x r = 1.00	18,860 y = -0.01 + 1.16x r = 1.00	16,981 y = -0.06 + 1.02x r = 1.00
< 0.4 km^{-1}	11,751 y = 0.01 + 0.32x r = [illegible]	11,751 y = 0.02 + 0.55x r = 0.76	13,072 y = 0.0[illegible] + 0.8[illegible]x r = 0.9[illegible]	11,7[illegible] y = -0.03 + [illegible] r = 0.94	11,727 y = 0.00 + 0.39x r = [illegible]
≥ 0.4 km^{-1}	5,229 y = -0.04 + 1.11x r = 1.00	5,229 y = 0.00 + 1.02x r = 1.00	[illegible],789 y = 0.[illegible] + 1.00x r = 1.00	[illegible],11[illegible] y = 0.0[illegible] + 1.0[illegible] r = 1.00	[illegible] y = -0.04 + [illegible] r = 1.0[illegible]
< 4.0 km^{-1}	15,991 y = -0.03 + 0.84x r = 0.86	15,991 y = 0.00 + 0.94x r = 0.96	17,780 y = 0.03 + 0.89x r = 0.99	1[illegible],[illegible]88 y = -0.0[illegible] + 1.[illegible] r = 0.99	16,[illegible] y = -0.04 + 0.8[illegible]x r = 0.[illegible]
≥ 4.0 km^{-1}	98[illegible] y = 0.0[illegible] + [illegible] r = 0.[illegible]	98[illegible] y = 0.04 + 0.94x r = 0.99	1,081 y = 0.02 + 0.98x r = 1.00	1,[illegible] y = [illegible] r = 1.00	9[illegible] y = [illegible] r = 1.00

given as well as the equations and correlation coefficients. MAWS 88 was chosen because it appeared to be the "best" data set and because a variety of weather conditions occurred in that time period. A summary of the Otis AFB weather observations reported during MAWS 88 are given in Table 4. Table 3 shows that the three scatter meter calibrations were reasonably consistent in each range. The extinction coefficients varied from 0.03 to 24 km^{-1}. The correlation coefficients remained high, lowering slightly to 0.94 in the < 0.4 km^{-1} range. The transmissometer data reaffirm that they do not provide good information beyond their effective range of 1.6 km^{-1} and 1.0 km^{-1} for 91.4 m and 152.4 m transmissometer,

respectively. In the low extinction range, the transmissometer correlation coefficients were much lower than anticipated.

Table 4. Summary of Otis AFB Weather Observations 17 Dec-30 Dec 1982 (MAWS 88)

DATE	VISIBILITY (MI)	WEATHER/OBSTRUCTIONS TO VISION*	TEMPERATURE (°F)
17 DEC	12-15		34-48
18 DEC	3/4-20	S-	33-36
19 DEC	1 1/2-20	R-; S-; SW-; RW-; L-F; R-F	36-40
20 DEC	1 1/2-10	L-F; R-F; L-S-; ZL-F; S-R-F; F	34-40
21 DEC	5-15	R-; S-	33-35
22 DEC	15		28-38
23 DEC	1/2-20	S; S-F	29-34
24 DEC	3/4-12	R-; R-S; R-L; L-F; R-L-F; F	32-52
25 DEC	1/8-5	F	47-55
26 DEC	5-20	F	49-56
27 DEC	12-20		32-49
28 DEC	1/4-20	R-; L-; L-F; F	42-56
29 DEC	1/8-20	F; R-F; R-	46-60
30 DEC	12-15		42-50

*R: Rain; RW: Rain Showers; L: Drizzle; ZL: Freezing Drizzle; S: Snow; SW: Snow Showers; F: Fog; (-) indicates light intensity

The time plots shown in Figures 5-8 indicate the response of the sensors to snow, 6-7 February; then to rain/fog, 7 February; and later to drizzle/fog, 8 February. As in the data summary (Table 2), the plots show that the FOG-15 (F15) had a greater response to obscuration than either of the other two scatter meters. Ten cm of wet snow fell during the 6-7 February storm. Apparently, as in the Eglin test, the TVM's heaters were not able to cope with the wet snow; the windows became partially obscured, attenuating the signal. As the weather changed to rain (7-8 February), the windows cleared and the TVM's response increased. Except

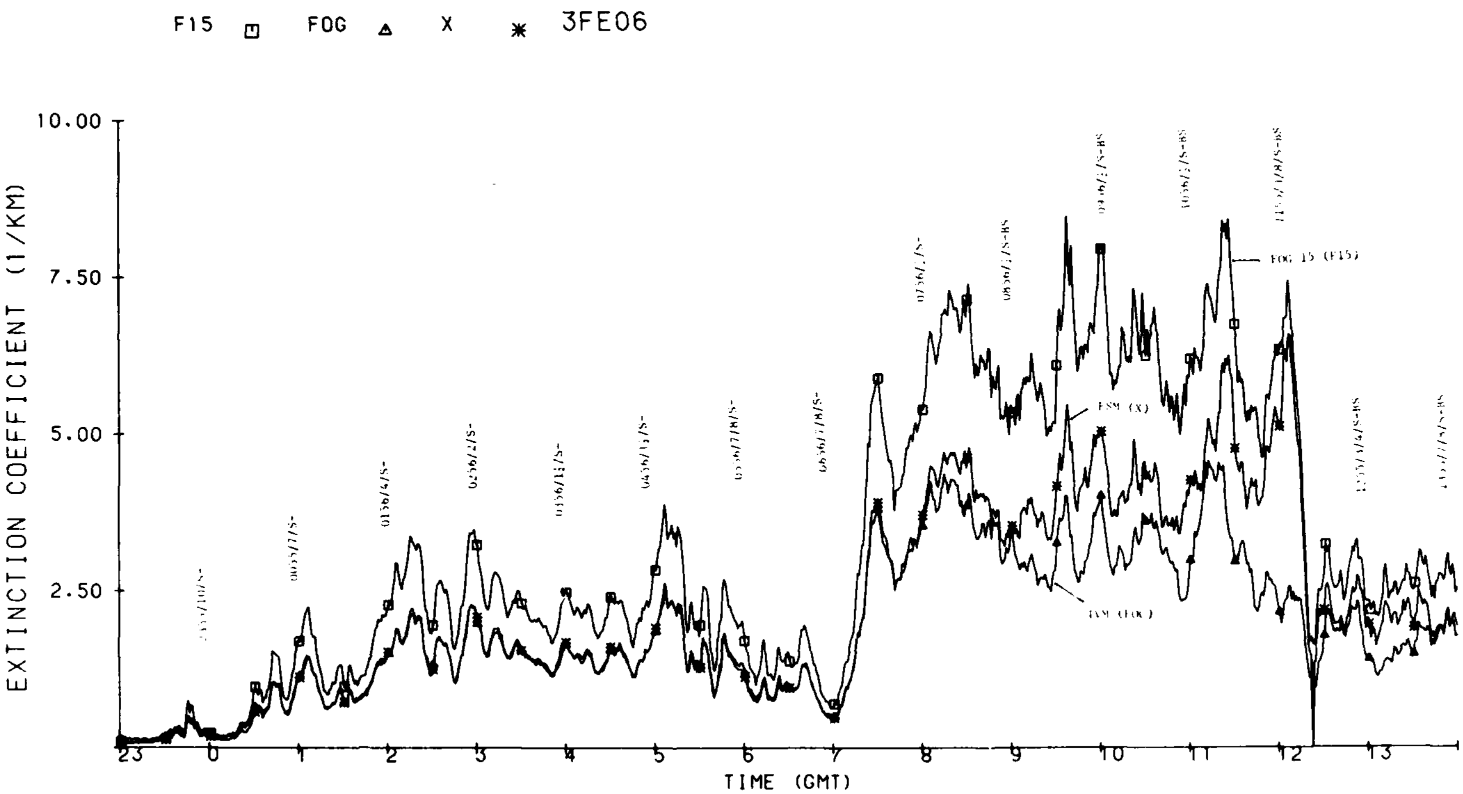


Figure 5. Time Plots of TVM (FOG), FOG-15 (F15), and FSM (X) in Light Snow (S-), Snow (S), and Blowing Snow (BS) Conditions, 6-8 Feb 1983

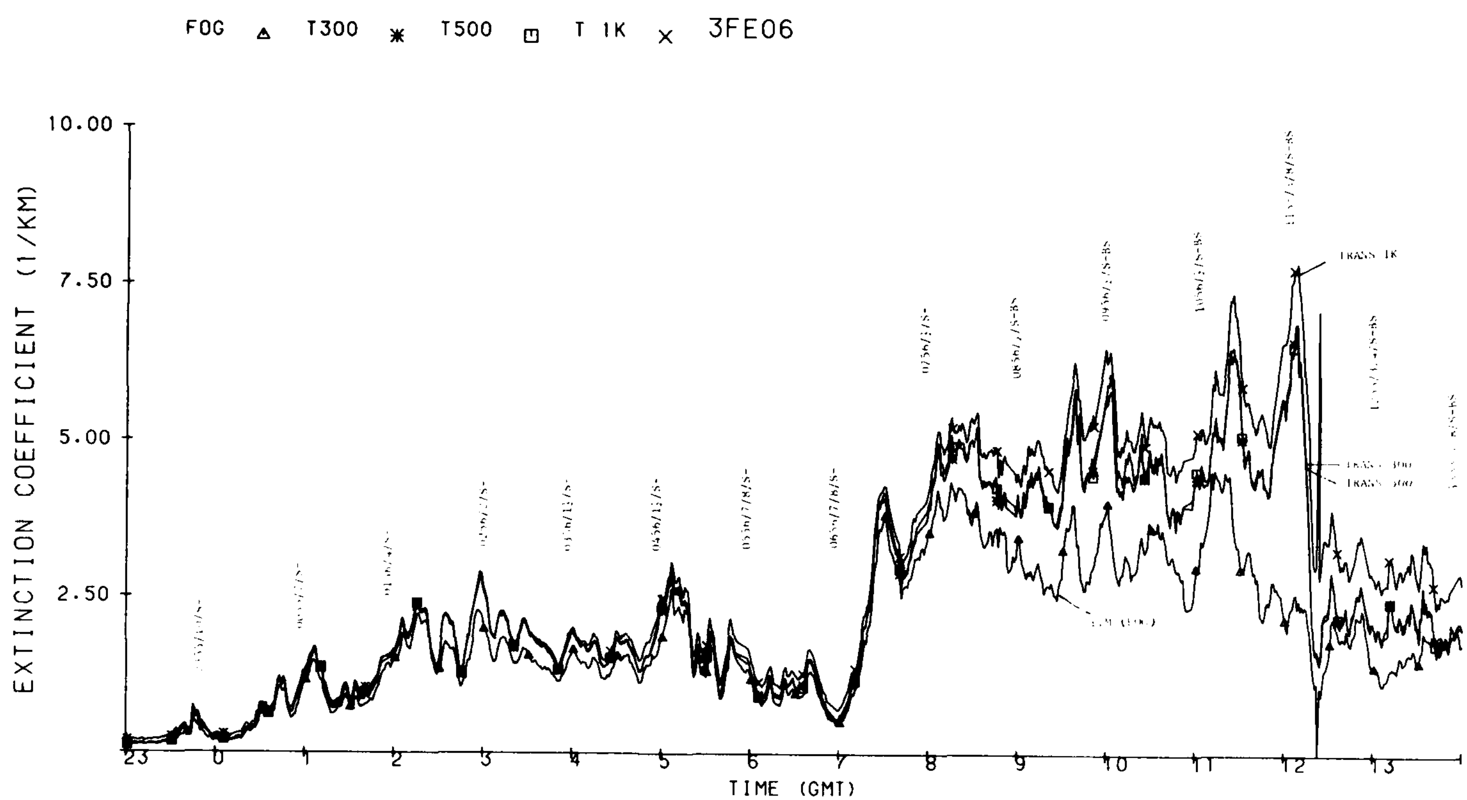


Figure 6. Time Plots of TVM (FOG), and 300-, 500-, and 1K-ft Transmissometers in Light Snow (S-), Snow (S), and Blowing Snow (BS) Conditions, 6-7 Feb 1983

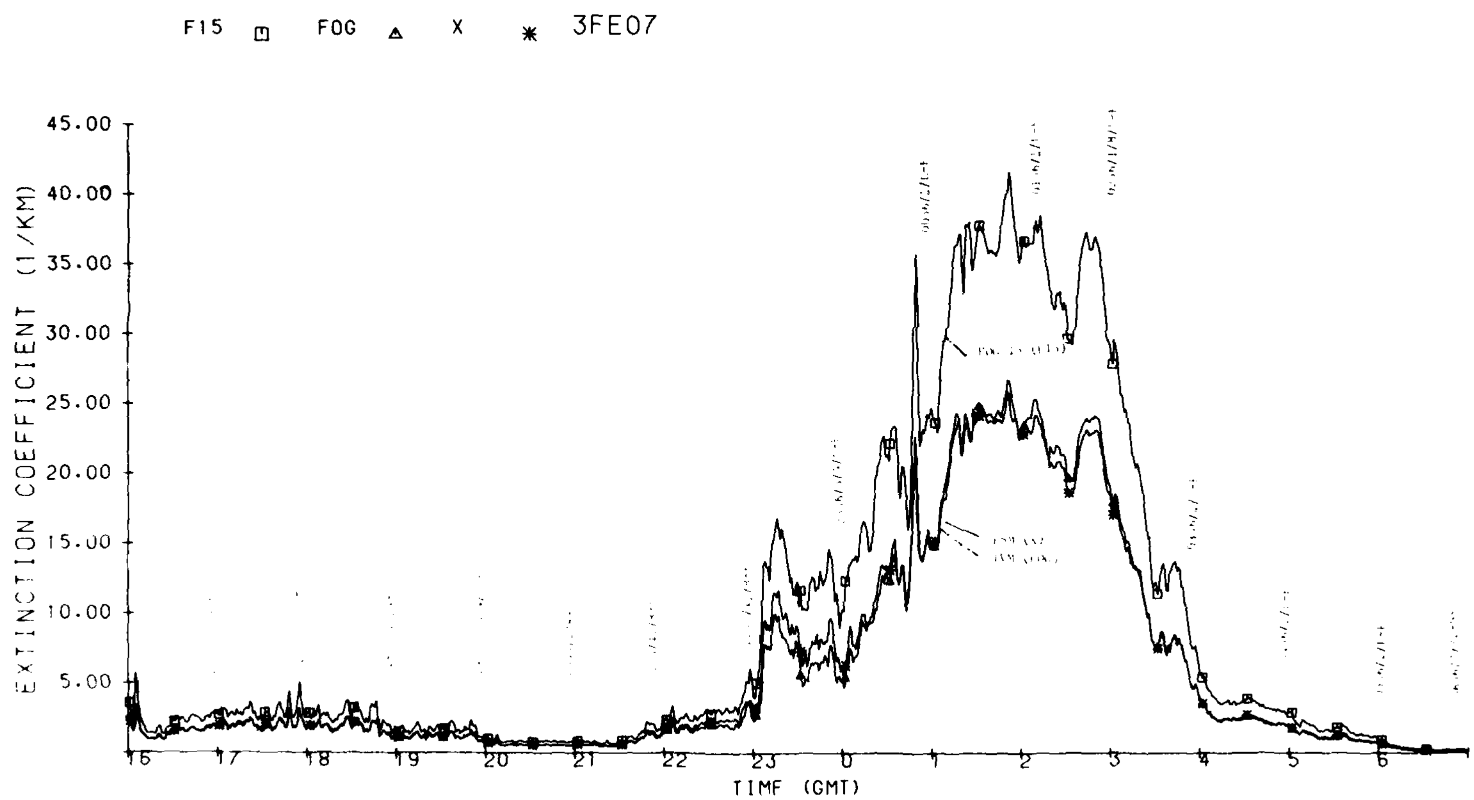


Figure 7. Time Plots of TVM (FOG), FOG-15 (F15), and FSM (X) in Rain (R), Drizzle (L), Freezing Drizzle (ZL), and Fog (F) Conditions, 7-8 Feb 1983

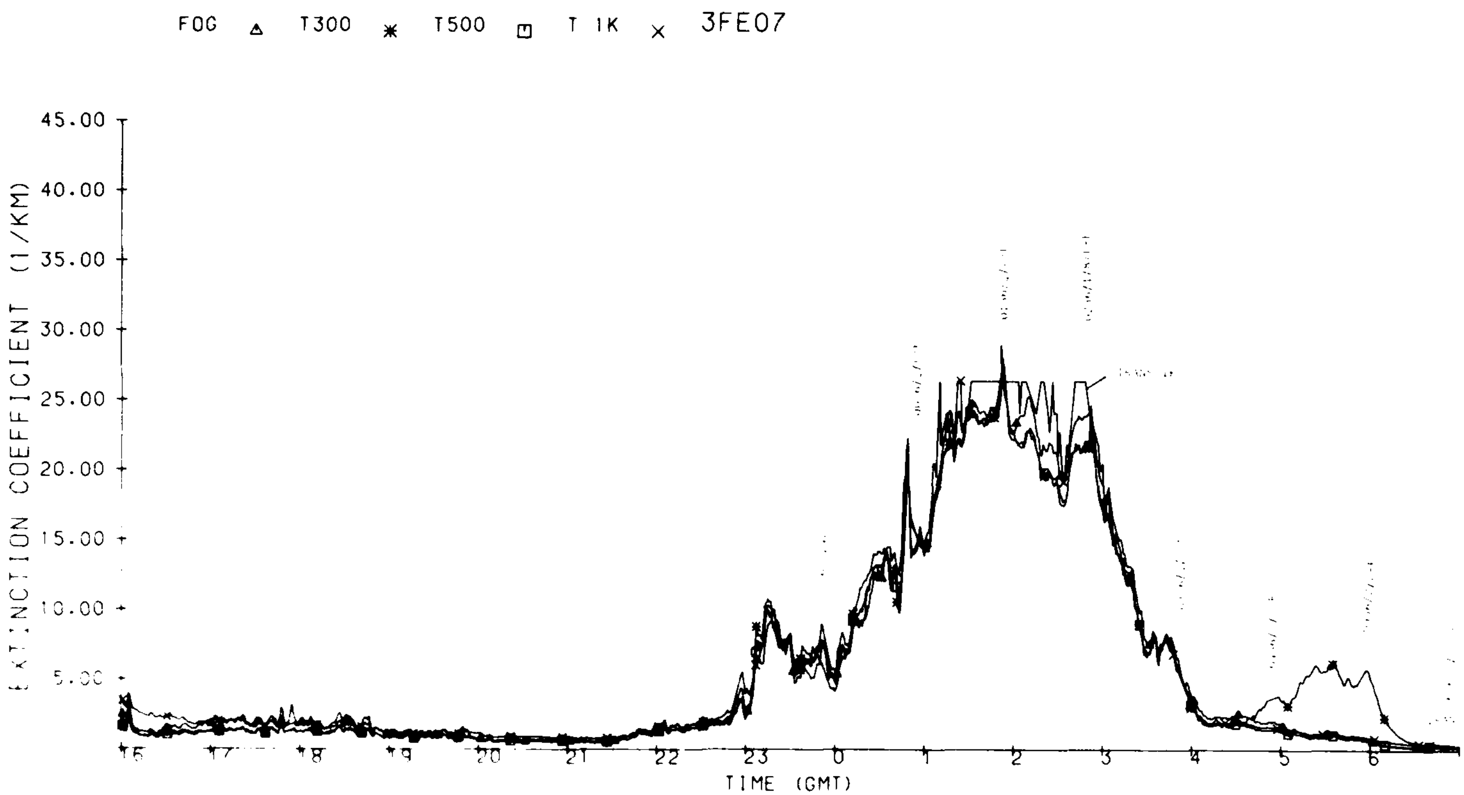


Figure 8. Time Plots of TVM (FOG) and 300-, 500-, and 1K-ft Transmissometers in Rain (R), Drizzle (L), Freezing Drizzle (ZL), and Fog (F) Conditions, 7-8 Feb 1983

for the time the TVM's windows were partially obscured, its response to the various weather conditions correlated with the other sensors with minor variations.

The TVM and FSM had an exceptional one-to-one correspondence during the falling snow, 0100 to 0800, 7 February. The two meters corresponded well throughout the rain/fog episode. As the rain changed to drizzle, the TVM had a lesser response to the obscuration than the FSM had; at 0030, the response of the two meters became similar; after 0130, the TVM's response was slightly greater; and, finally, at 0300, both meters corresponded again. A comparison of the TVM with the two test transmissometers shows the response of the TVM in snow was less than the transmissometers even before the TVM's windows became partially obscured. In the rain/fog and drizzle/fog episodes, the TVM's response was either the same or slightly greater than that of the transmissometers. With the information obtained during the test, it is not possible to ascertain whether these minor variations are a result of instrumental and/or spatial differences.

It should be noted that there is no explanation for the singular excursion made by the 91.4 m transmissometer from 0400 to 0700, 8 February. Also, the third transmissometer, T 1K, plotted with the other two transmissometers, is a 305-m baseline system that was being installed and was not fully operational at the time of the test. Sensor comparison plots corresponding to the time plots in Figures 5-8 are given in Appendix D.

The TVM was calibrated on 16 November 1982 and then recalibrated 6 months later on 19 May 1983 (see Table 5). Two calibration discs and two neutral density

Table 5. Calibration of TVM, 16 Nov 1982 and 19 May 1983 (Readings in Volts)

	16 NOV 1982	19 May 1983						
		Before Cleaning	Change in Reading	Percent Change	Receiver Cleaned	Projector Cleaned	Change in Reading	Percent Change
Cal. Disk 001 Filter #1	0.551	0.522	-0.029	-5.3	0.535	0.544	-0.007	-1.3
Cal. Disk 007 Filter #1	1.113	1.055	-0.058	-5.2	1.080	1.099	-0.014	-1.3
Cal. Disk 001 Filter #2	2.532	2.428	-0.104	-4.1	2.472	2.491	-0.041	-1.6
Cal. Disk 007 Filter #2	5.125	4.867	-0.258	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Zero Reading	0.0073	0.0042	-0.0031					

filters were used to obtain a total of four calibration points. In addition, a zero check was made by covering the receiver. The zero reading decreased 3.1 mV from 7.3 mV to 4.2 mV. Before the windows were cleaned, the calibration values

decreased 4.1 percent to 5.6 percent. After the windows were cleaned, the changes ranged from 1.2 percent to 2.6 percent. The changes were actually slightly less because the zero shift was not taken into account.

As a result of the testing of the scatter meters by both AFGL and DOT's Transportation Center, the contractor has made a number of changes in both the commercial meter and the TVM. These changes include:

(1) a modified band pass filter circuit and upgraded signal processing electronics;

(2) replacement of the filter wheel with a slide-in holder for inserting the calibration neutral density filter;

(3) modification of the projector chopper system;

(4) replacement of the projector and receiver heaters with proportionally controlled heaters; and

(5) replacement of the two globular light blocks with a single thin aluminum paddle.

These changes should improve the operation and reliability of the scatter meter. In particular, they should provide the meter with better long-term zero stability.

The changes have been incorporated into the TVM. Figure 9 shows the modified TVM being bench-checked at the AFGL Weather Test Facility. Evaluation of the modified TVM will be conducted at the test site as part of a program aimed at providing Air Weather Service (AWS) with a visibility measuring capability compatible with the all-weather microwave landing system to be used for both fixed-base and tactical air-field applications.

4. CONCLUSIONS AND RECOMMENDATIONS

Extensive testing of the TVM has demonstrated that it can provide AWS with accurate and timely visibility information in support of AF tactical bare-base operations. It can be installed easily by one individual; maintenance and calibration routines are simple; and it has a covert capability. Over a 6-month period, its calibration changed only 2.6 percent. Recent modifications by the contractor should improve its long-term zero stability.

It is strongly recommended that AWS incorporate this instrument into its inventory for tactical operations. Also, since forward-scatter measuring visibility meters have been shown to provide accurate determinations of extinction coefficients over such a large dynamic range (3-4 decades) and they are inexpensive, AWS should consider using forward-scatter measuring visibility meters in conjunction with or as replacements for the standard transmissometer.

Figure 9. Modified TVM Being Bench Checked at AFGL/WTF, Otis AFB, Mass.

References

1. Moroz, E.Y., and Brousaides, F.J. (1980) Survey of Sensors for Automated Tactical Weather Observations, AFGL-TR-80-0195, AD A094121.

2. Moroz, E.Y., Sheets, S.J., and Morrissey, J.F. (1982) Evaluation of Selected Sensors for Automated Tactical Weather Observations, AFGL-TR-82-0191, AD A122172.

3. Hanley, J.T. (1982) Final Report, Documentation of Extinction and Particle Size Measurements for Chamber Tests of May 1982, Arvin Calspan, Advanced Technology Center, Buffalo, N.Y.

4. Burnham, D.C. (1983) Evaluation of Visibility Sensors at the Eglin Air Force Base Climatic Chamber, DOT/FAA/PM-83/29.

5. Tahnk, W.R., and Lynch, R.H. (1978) The Development of a Fixed Base Automated Weather Sensing and Display System, AFGL-TR-78-0009, AD A054805, Instrumentation Papers No. 260.

Appendix A

Engineering and Performance Requirements for Preproduction Tactical Visibility Meter

A1. BACKGROUND

Visibility information is required by the Air Force to support tactical bare-base operations. Under a competitive AF contract, F19628-79-C-0185, a developmental visibility meter was designed and fabricated by Wright and Wright, Inc., Oak Bluffs, Mass., to meet this requirement. The design and subsequent testing of the developmental instrument demonstrated that it satisfies the requirements of a tactical visibility meter for operations at bare-base airfields. The purpose of this procurement is to obtain a cost-effective preproduction version of the meter that meets the engineering and performance capabilities of the developmental model.

A2. MAINTAINABILITY

The equipment shall be designed so that the maximum downtime per failure does not exceed 2 hours. Test points and test features shall be in accordance with MIL-STD-415. These test points shall be brought out to an accessible location, with no removal of modules or components required for measurement of test parameters. When test points provide access to voltage and/or wave forms to be measured against ground, at least one conveniently located ground test-point shall

be furnished on the chassis. All internal controls and adjustments shall be located so as to be readily accessible. Test points must be buffered to make them short-circuit proof.

A3. RELIABILITY

The equipment shall be designed to provide a mean-time-between-failure (MTBF) of at least 2400 hours of continuous operation (90 percent probability that there will be zero failures in 2400 hours of operation).

A4. SERVICE CONDITIONS

The equipment shall be designed to operate without damage or degradation of performance when subjected to all combinations of the following service conditions:

(1) The instrument shall operate from an input voltage source providing 115 VAC ±10 percent with fluctuations of 2 percent or less and rates of change of 2.5 percent per second or less, and a frequency range 47-63 Hz with fluctuations of 1 percent or less and rates of change of 2.5 percent per second or less.

(2) Any dc power supply used in the system shall be short-circuit-proof and shall not be damaged when its output is shorted.

(3) Input circuits shall be protected by circuit breakers or fuses.

The visibility instrument shall operate in the following climatic conditions:

(1) Temperatures between -58°F (-50°C) to +130°F (+54.5°C)

(2) Relative humidities from 5 percent to 100 percent

(3) Pressures from 18.42 to 32.40 in of mercurcy

(4) Rainfall at the rate of up to 4 in (0.1 m) per h for a period of 2 h

(5) Blowing snow and snow falling at the rate of up to 4 in (0.1 m) per h for a period of 2 h

The equipment shall be designed to meet the requirements of Test Method 516, Procedure VI of MIL-STD-810 (Bench Handling Stock), and shall be designed and constructed so that no fixed part becomes loose and no movable part of permanently set adjustment shifts its setting when subjected to this test.

The equipment shall be designed to withstand the shock and vibrations encountered while being transported over rough terrain without necessitating optical re-alignment.

The meter shall provide the Air Weather Service (AWS) with the means to furnish Air Force pilots and forecasters visibility information in the tactical bare-base situation. The range of visibility information required under all obscuring

conditions is, in terms of extinction coefficients, $2 \times 10^{-2} ft^{-1}$ ($64 \ km^{-1}$) to $4.5 \times 10^{-5} ft^{-1}$ ($0.15 \ km^{-1}$).

The instrument shall determine the visibility or equivalent extinction coefficient from a measurement of atmospheric forward scatter of light. The developmental visibility meter shall be made available to the contractor as government-furnished equipment.

In addition to the above capabilities, the preproduction meter shall have the following features:

(1) Configuration: The instrument shall be configured so that it can be readily transported and installed. Installation can be accomplished by one person. No alignment shall be required during installation.

(2) Modulation: Coded modulation at a suitable rate shall be used to provide and optimum signal-to-noise ratio and to minimize the adverse effect of bright modulated backgrounds on the extinction measurement.

(3) Calibration: Means shall be provided to calibrate the instrument to within ± 1 percent of equivalent extinction coefficient. It shall be possible to calibrate the instrument in the field. The instrument shall be designed to maintain its calibration to within ± 5 percent of equivalent extinction coefficient for a minimum period of 6 months during normal operation. The condition of the outer optical surfaces may be excluded from this requirement.

(4) Electronics: Only current state-of-the-art electronics shall be used.

(5) Weight: The weight of the instrument shall not exceed 50 lb.

(6) Operation in Hostile Areas: The instrument shall not be visible from internal light sources when operating in a hostile area. The instrument shall have a covert operation capability in addition to its normal mode of operation.

A5. TEST/DEMONSTRATE

The contractor shall test and/or demonstrate that the tactical visibility meter meets the following requirements:

(1) Measurement range

(2) Configuration

(3) Modulation

(4) Calibration. Only the requirement that means be provided to calibrate the meter to within ±1 percent of equivalent extinction coefficient shall be demonstrated.

(5) Weight

(6) Covert operations

Appendix B

Time Plots of Evaluation Model TVM (F15) and Calspan Extinction Meters Measurements Obtained in Chamber Fog and Haze Conditions

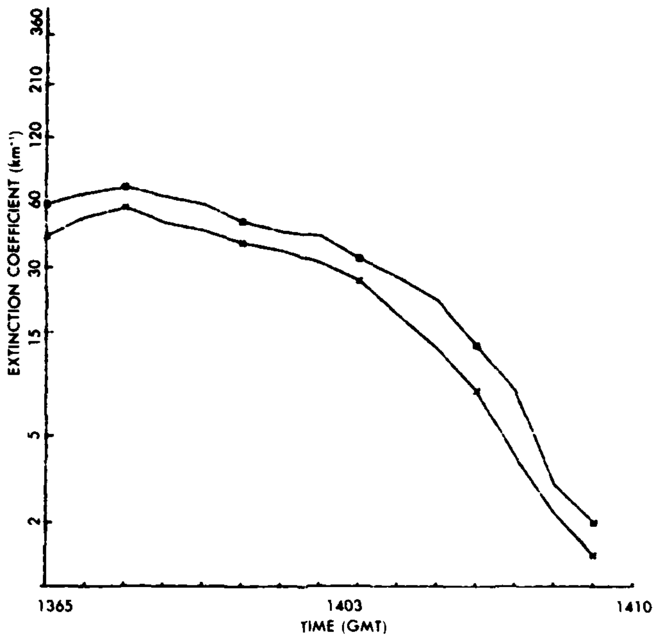


Figure B1. Run 3—Fog

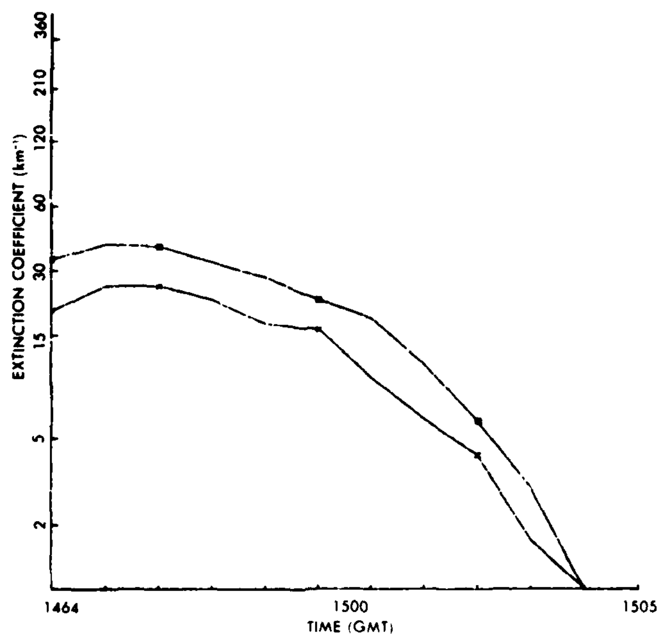


Figure B2. Run 4—Fog

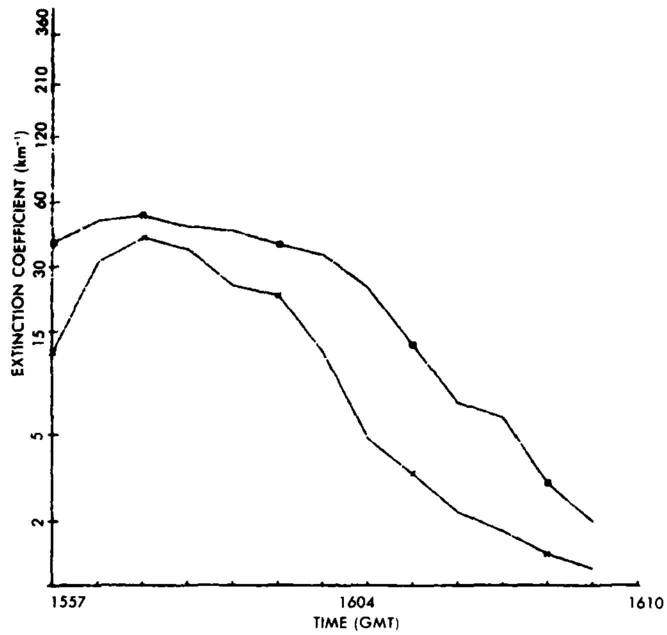


Figure B3. Run 5—Fog

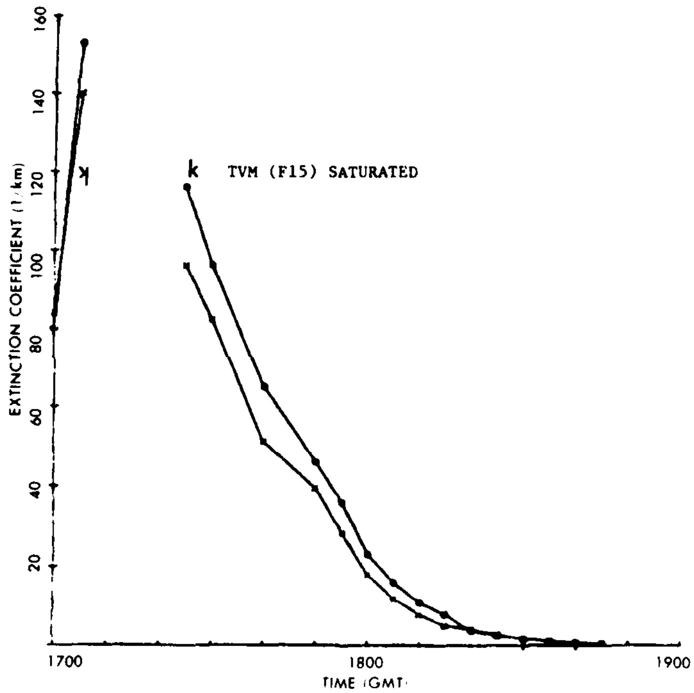


Figure B4. Run 6—Haze

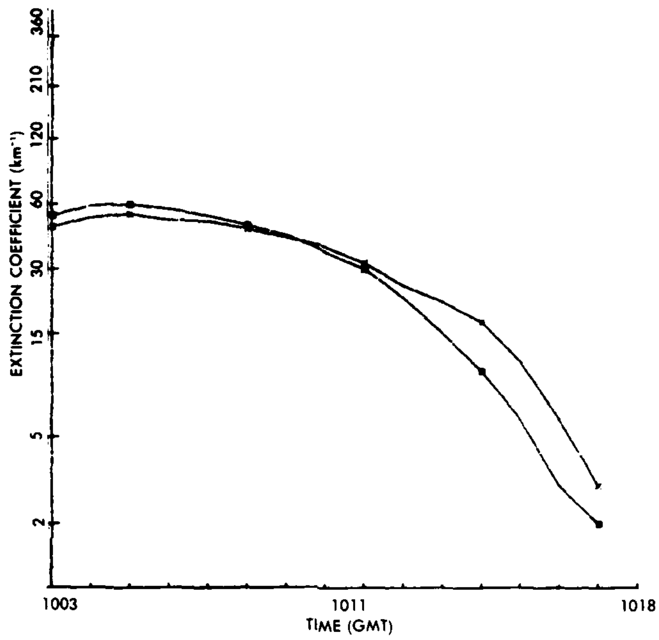


Figure B5. Run 7—Fog

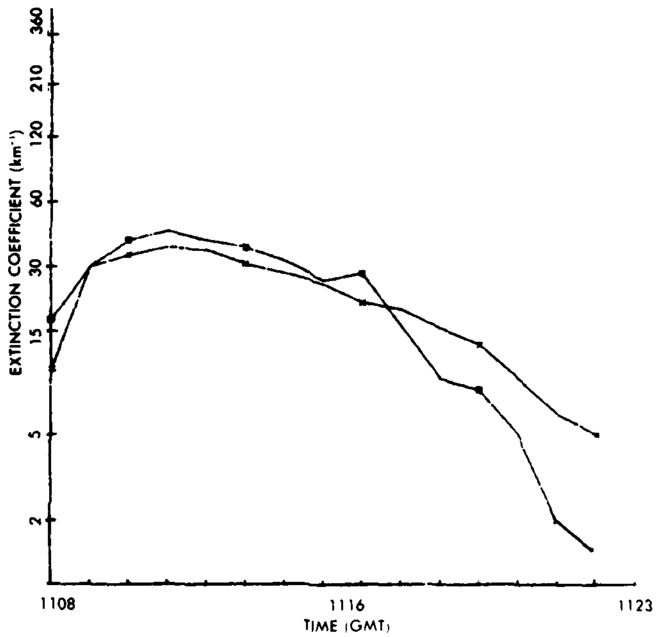


Figure B6. Run 8—Fog

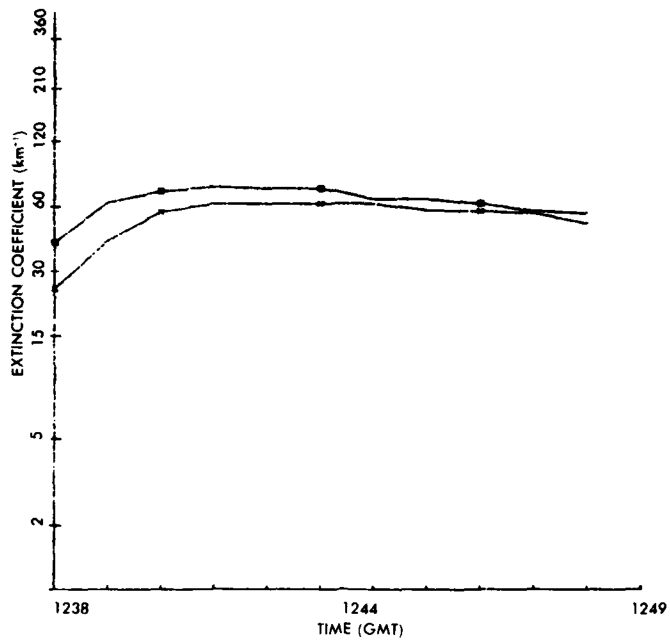


Figure B7. Run 9—Fog

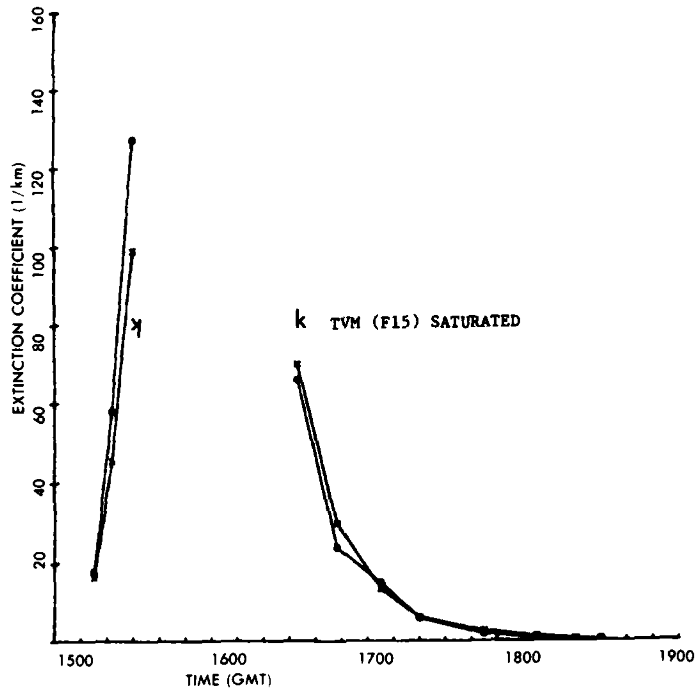


Figure B8. Run 10—Haze

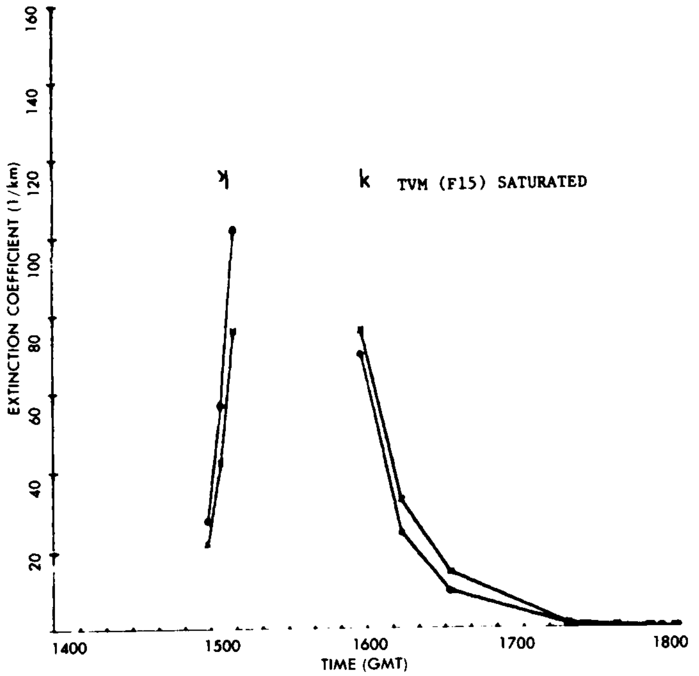


Figure B9. Run 13—Haze

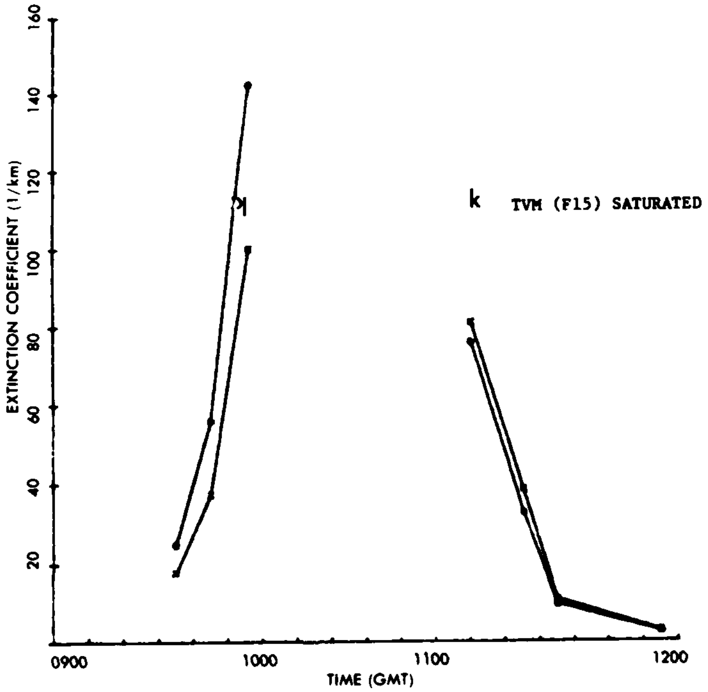


Figure B10. Run 14—Haze

Appendix C

Wright and Wright, Inc., TVM Test Data

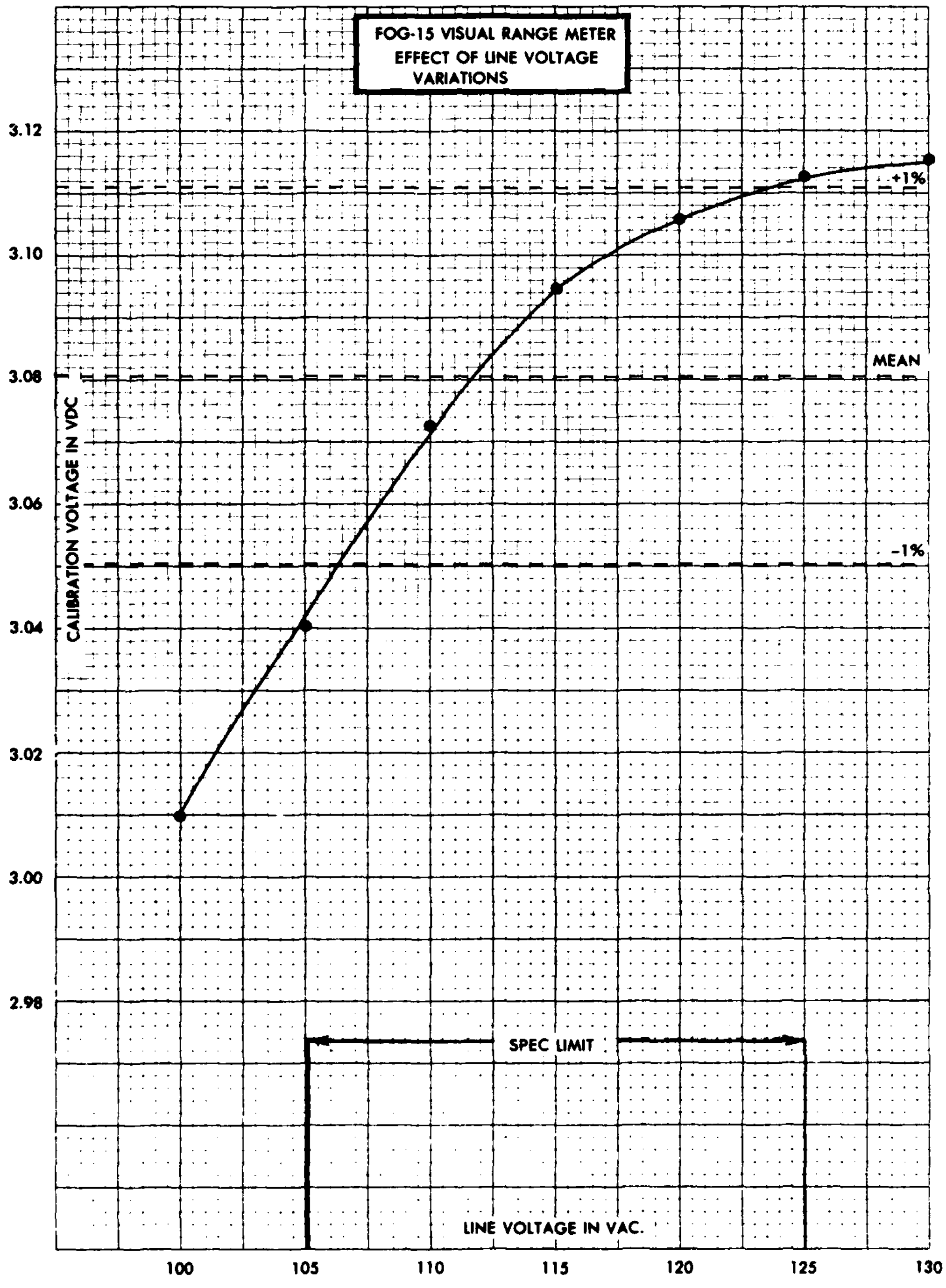


Figure C1. FOG-15 Visual Range Meter: Effect of Line Voltage Variations

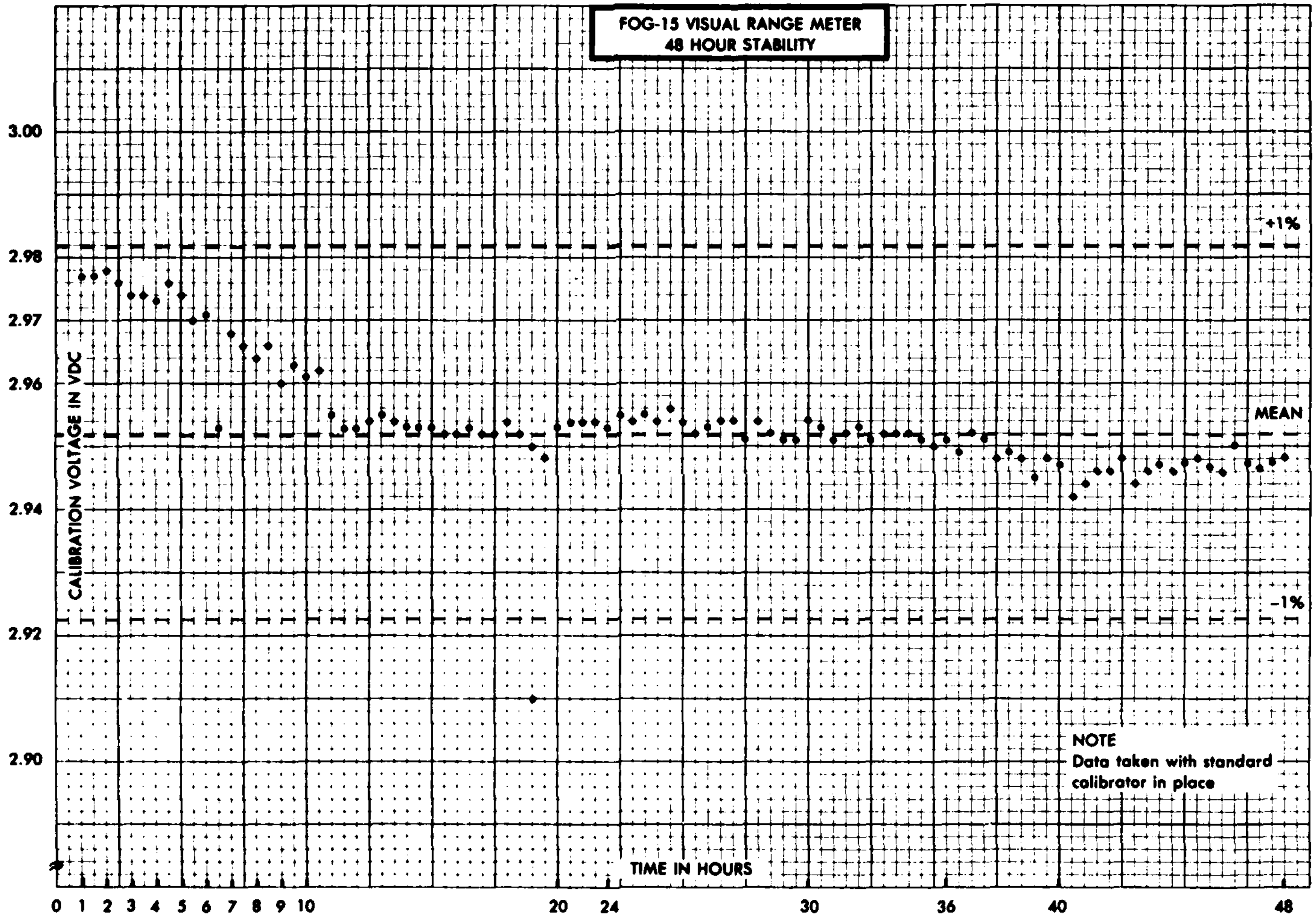


Figure C2. FOG-15 Visual Range Meter: Effect of Line Voltage Variations

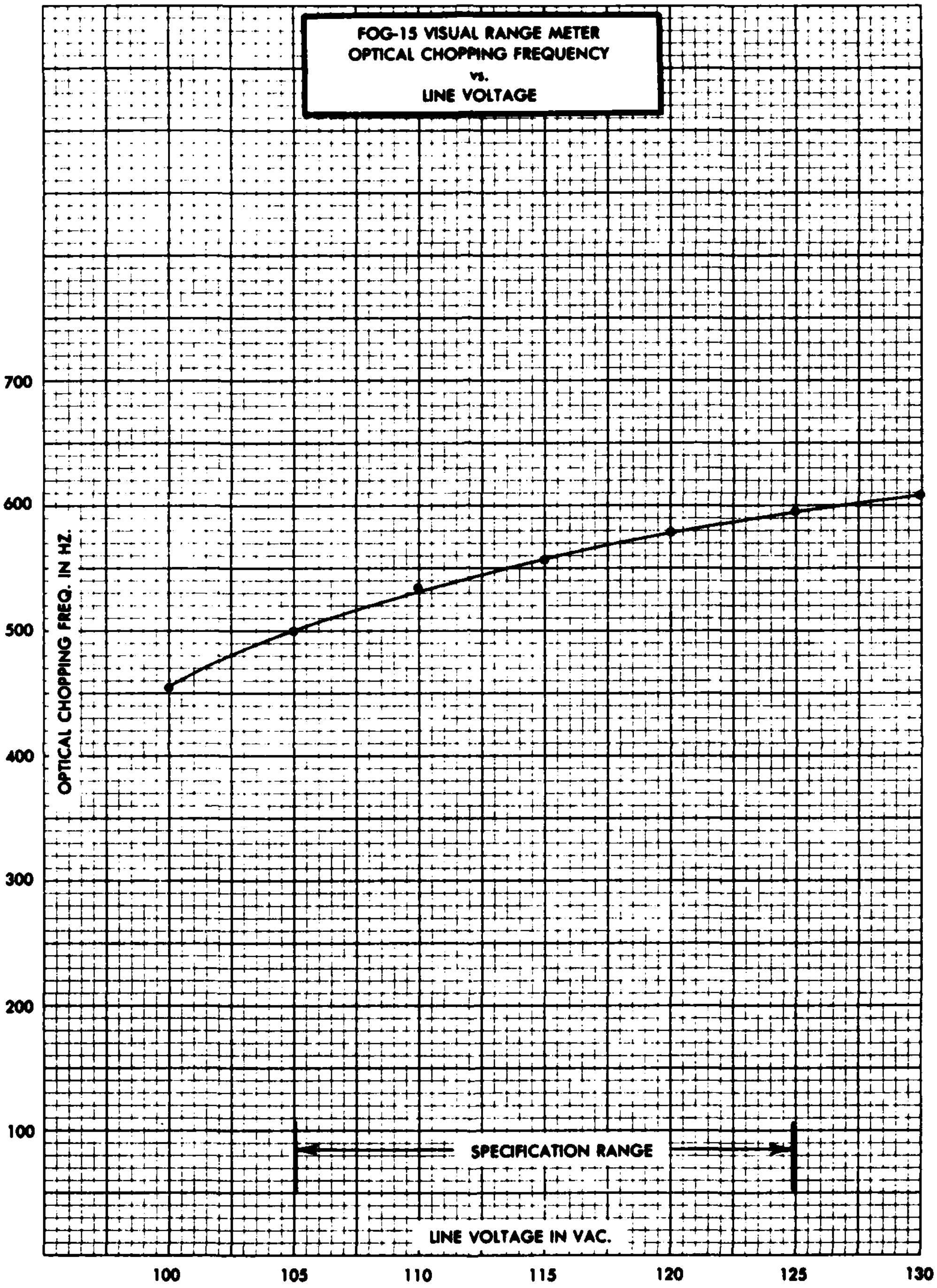


Figure C3. FOG-15 Visual Range Meter: Optical Chopping Frequence vs Line Voltage

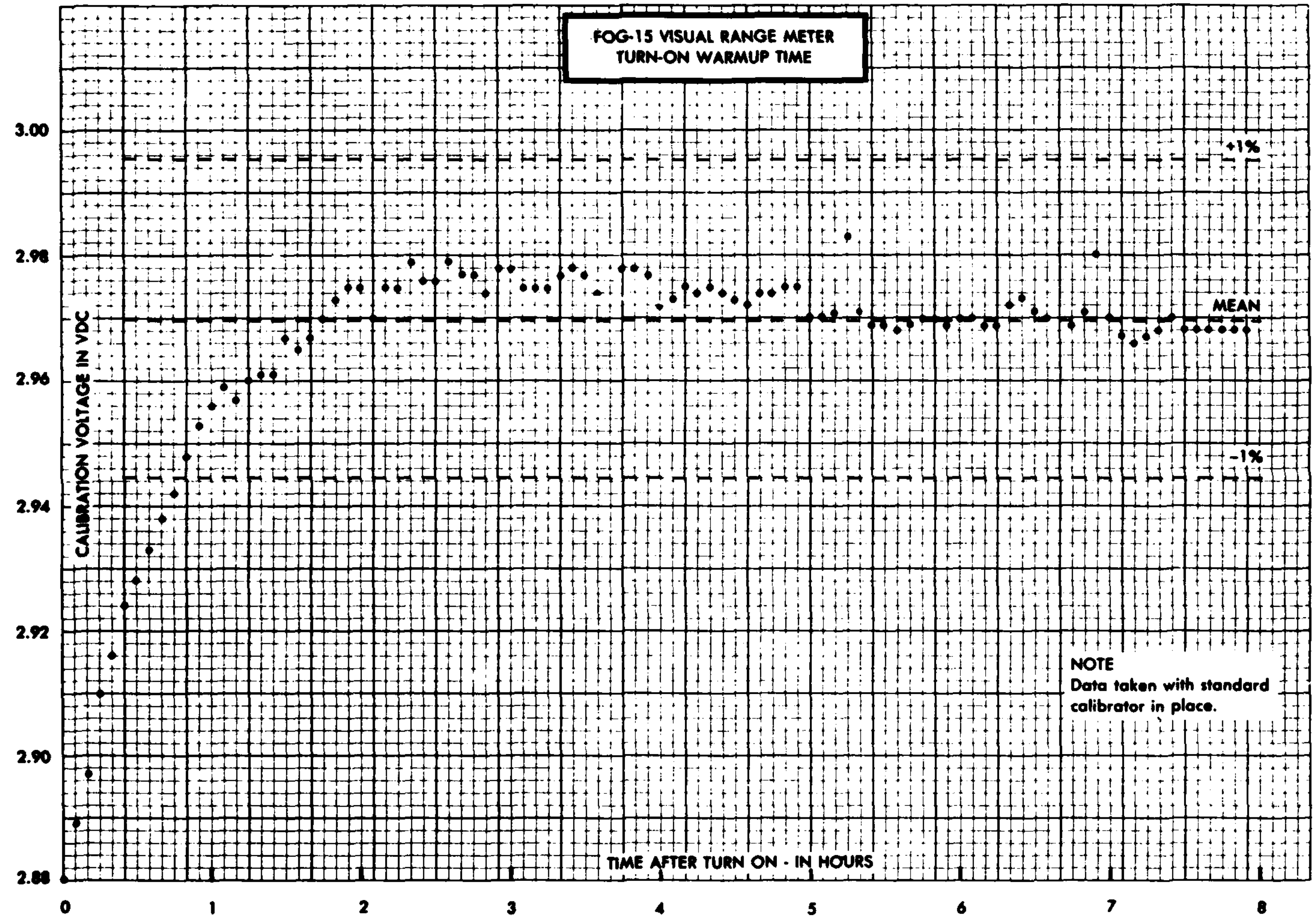


Figure C4. FOG-15 Visual Range Meter: Turn-On Warmup Time

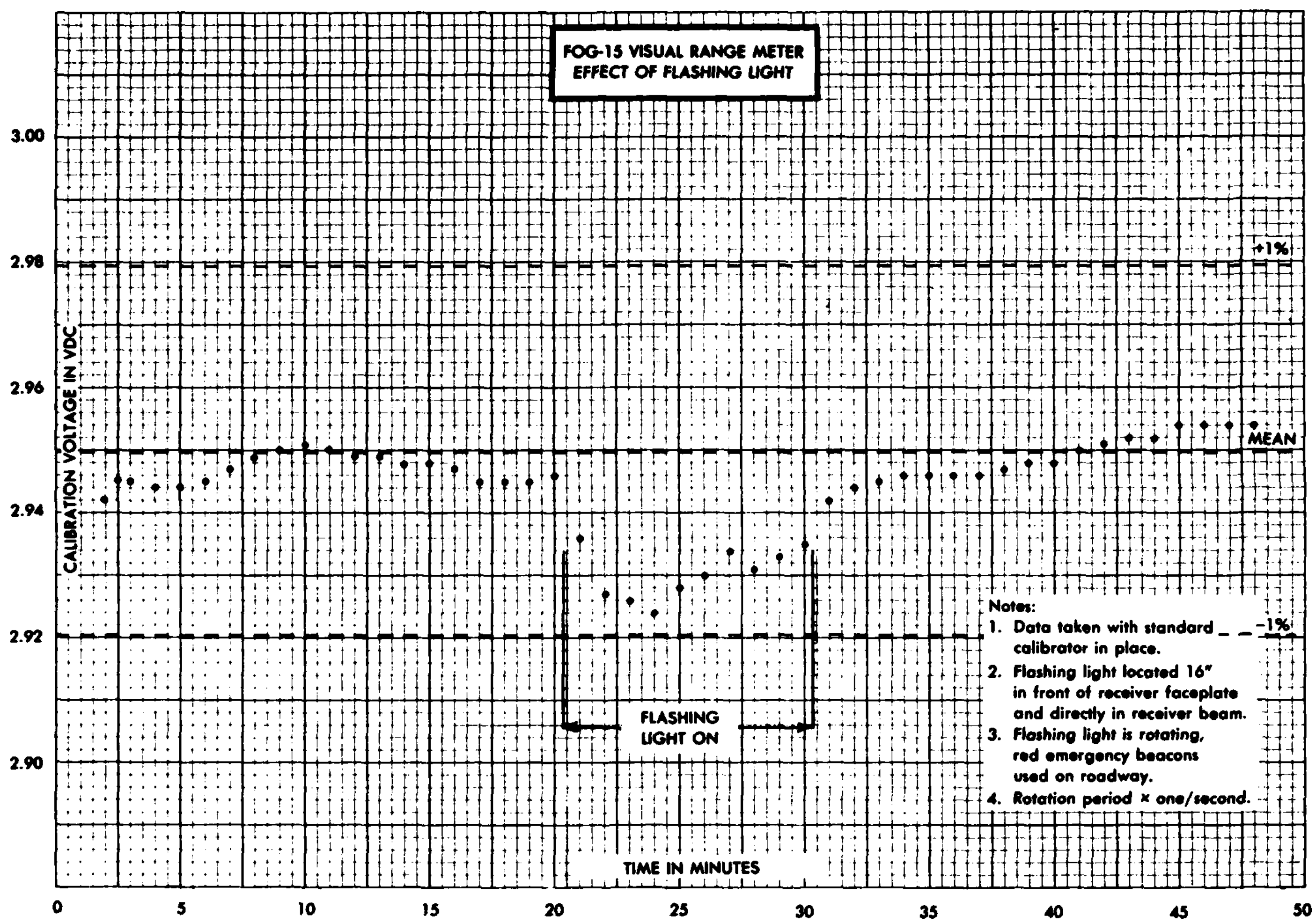


Figure C5. FOG-15 Visual Range Meter: Effect of Flashing Light

QUALITY CONTROL RECORD Sig Proc Bra: 015

FOG-15 Visibility Range Meter S/N 015 Air Force

Note: Section and paragraph numbers refer to Wright and Wright, Inc. Quality Control Procedure for the FOG-15 Visibility Range Meter. All steps to be dated and initialed.

SECTION 1 FINAL ELECTRICAL TESTS

HER 4/5/82	1.1	Instrument zero: 100 VAC: .005 VDC 115 VAC: .004 VDC 130 VAC: .004 VDC
HER 4/5/82	1.2	Optical calibration: 100 VAC: 1.082 VDC 115 VAC: 1.051 VDC 130 VAC: 1.041 VDC
________	1.3	Electrical calibration: 100 VAC: ______ VDC 115 VAC: ______ VDC 130 VAC: ______ VDC
HER 4/1/82	1.4	Receiver heater: 4/1/82 Minimum heat position 4/1/82 Maximum heat position 4/1/82 Thermostat
HER 4/1/82	1.5	Transmitter heater
HER 4/1/82	1.6	Optical block heaters

SECTION 2 FINAL MECHANICAL INSPECTION

HER 4/5/82	2.1	Integrity of hardware
HER 4/5/82	2.2	Chopperwheel clearance
HER 4/6/82	2.3	Integrity of wiring

SECTION 3 FINAL OPTICAL AND VISUAL INSPECTION

HER 4/6/82	3.1	Optics
HER 4/6/82	3.2	Serial number labels
HER 4/1/82	3.3	Alignment

Appendix D

Comparison Plots of Measurements Obtained by TVM and AFGL Weather Test Facility Extinction Meters During an Extended Precipitation/Fog Episode at Otis AFB, Mass., 6-8 February 1983

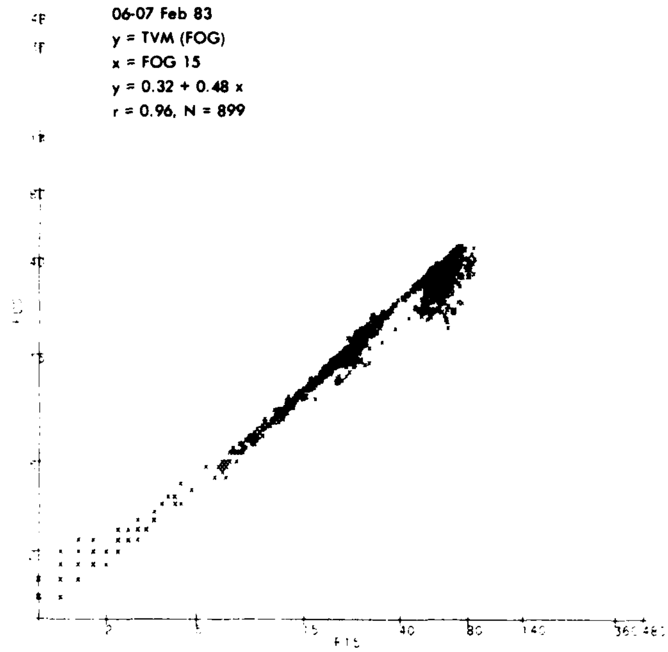


Figure D1

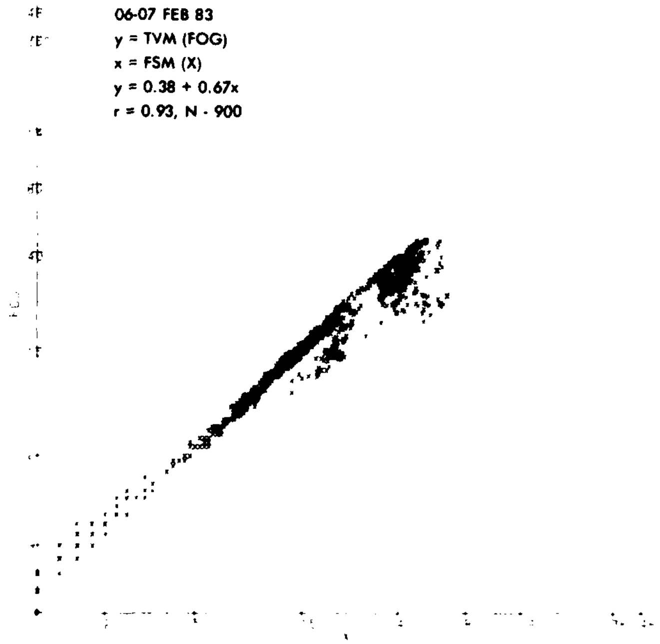


Figure D2

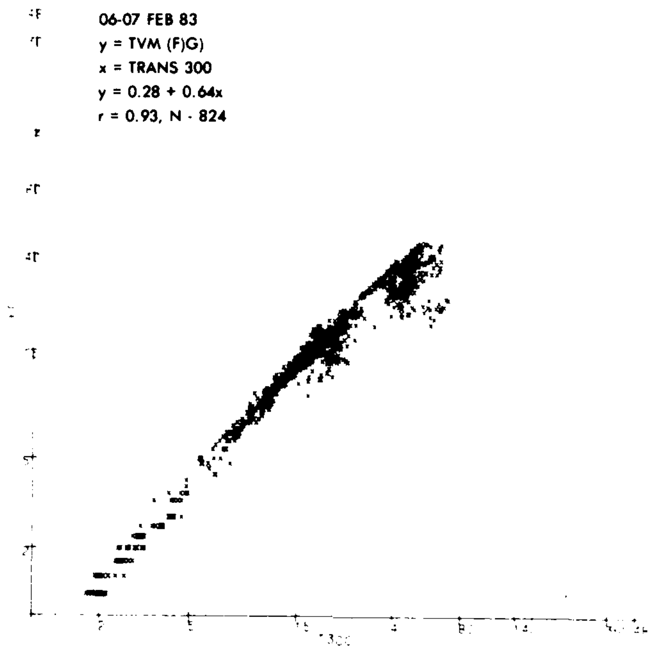
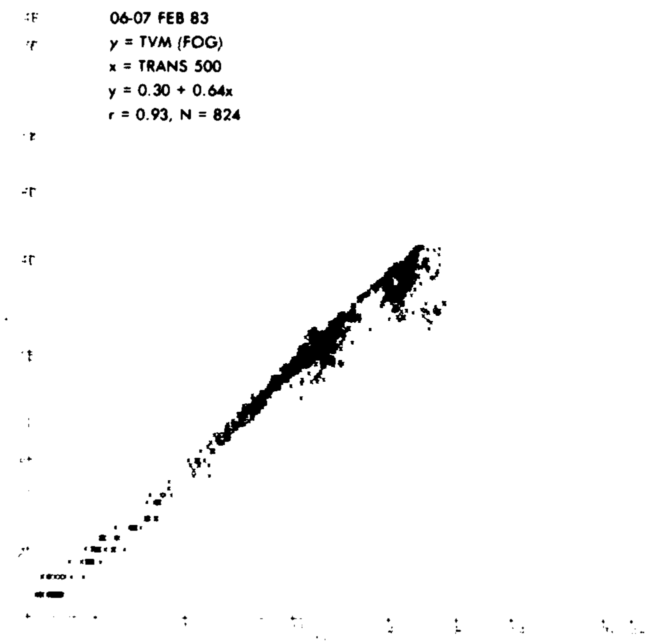


Figure D3



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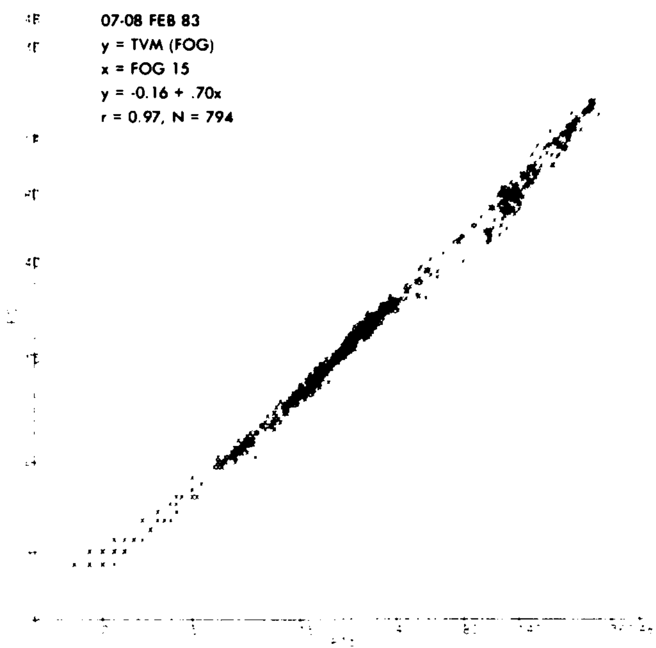

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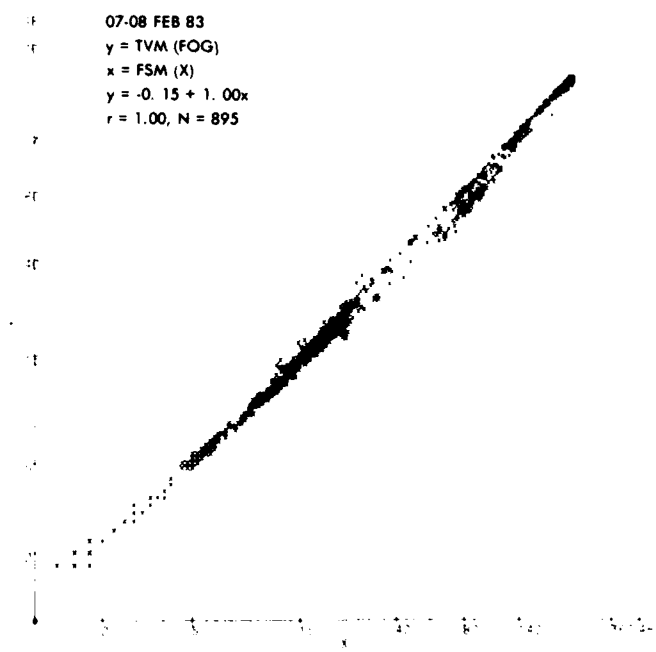

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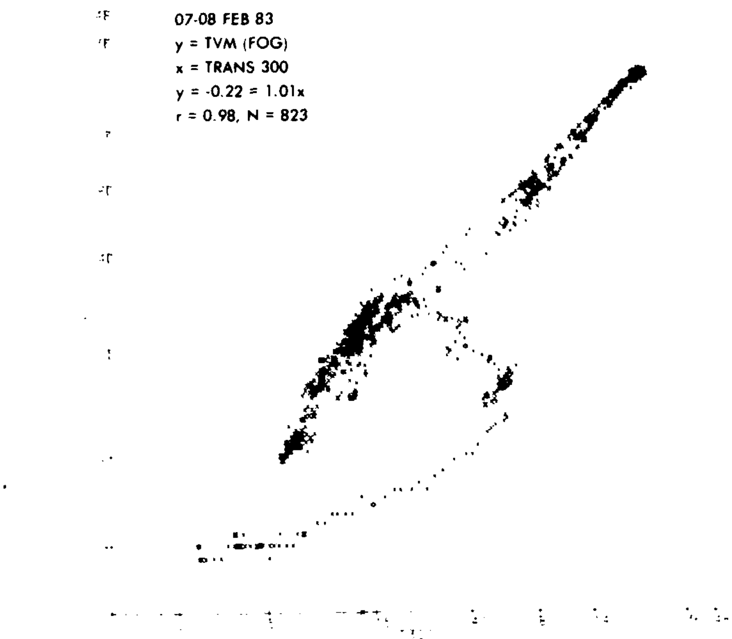

Figure D7

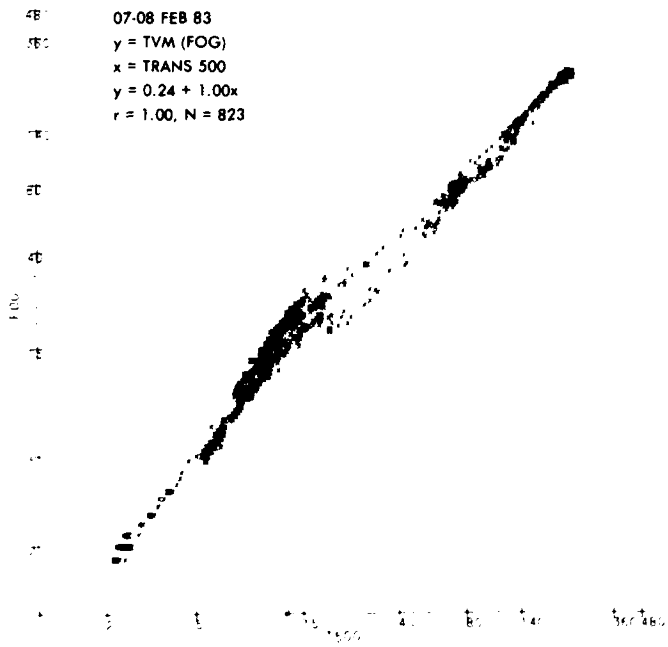

Figure D8